

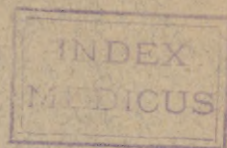
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AN EXPLANATION
OF THE PHENOMENA OF
Immunity and Contagion,

BASED UPON THE ACTION OF
Physical and Biological Laws.

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J. W. M'LAUGHLIN, AUSTIN.



Contagion consists in the transmission of communicable diseases from one individual to another through the agencies of contagia, the efficient causes of all contagious diseases; these contagia may be communicated by contact, through the atmosphere, or from infected articles, fomites.

Immunity signifies that condition of the body which opposes the development of contagious processes. The principles involved in the causation of contagion and immunity, therefore, lie at the very foundation of all knowledge of those laws which control infectious diseases.

The importance and wide application of these principles, and the successful efforts which nature has made in concealing them from man's knowledge, have stimulated him to great and laborious investigations, and have resulted in the production of many ingenious theories.

This subject has occupied a large share of my attention for many years. From observing nature's methods in other departments of science—how, through the action of physical laws, physical results are obtained—the conviction grew upon me that physical law would furnish the key that would unlock our problem. The subject was so complex, the observed phenomena were apparently so diverse and even contradictory, that a long time elapsed before I was able to report any progress. In 1887 I published the first results which I obtained by this method.* Notwithstanding the subject was still very hazy at that time, I could see how the laws of wave-motion, when applied to the motion of organic molecules, would explain some of the phenomena of contagion, but the complete elucidation of the subject had not yet dawned upon me. Francis Galton says: "Few intellectual pleasures are more keen than those enjoyed by a person who, while he is occupied in some special inquiry, suddenly perceives that it admits of a wide generalization, and that his results hold good in previously unsuspected directions." While thinking over the phenomena of contagion and immunity, and the laws of wave-motion, the beautiful law of interference occurred to me, when it flashed over me that the application of this law to molecular wave-motion completed the chain of evidence. I felt very much as I imagine did Archimedes when he sprang from his bath and ran naked, shouting "Eureka," through the streets of Syracuse.

Time will not allow an attempt to kaleidoscope the history and varied opinions regarding contagion; suffice it that in this, as in the evolution of other questions of science, the theories offered from time to time were based upon such information of the subject as was then known, and all possess some truth.

In the light of our present knowledge it can be safely asserted that contagium is a particulate substance; that it is capable, when suitably environed, of increasing itself indefinitely by multiplication of its particles; that in this increase it produces only its own kind, and does this as unerringly as do animal or vegetable species in their increase by generation. Thus a very small

**Etiology of Acute Infectious Diseases, Daniel's Texas Medical Journal.*

portion of small-pox virus or contagium, if inoculated under the skin of a susceptible person, will multiply and increase itself in the blood of this person, and pustules will form upon his body which will contain the same character of contagious substance, possessing the same distinctive properties, as that used in inoculation.

Or, a person with an infectious fever may infect a hundred or more persons with the same disease, transmitting to each one the amount and kind of contagium that he himself received at the time of his infection.

There is no known substance, neither a solid, a liquid, nor a gas, save and except a living organism, which is capable of increasing and multiplying its own kind in the manner thus described.

The striking similarity which is seen between fermentation and contagion has led many observers to believe that the latter, like the former process, is caused by microscopic organisms. As there are many kinds of fermentation, each kind resulting from the action of specific organisms—for example, alcoholic fermentation is caused by the yeast plant; acetic fermentation by the micrococcus aceti; butyric fermentation by the bacillus amblyobacter, etc.—so it is claimed that each specific infection has its specific bacterium or bacteria. I do not think that it can be claimed that only one species or variety of bacteria will produce a specific infection, for example, a specific infectious fever. It is well known that fermentation—alcoholic, acetic, or butyric—may result from the action of more than one kind of ferment or bacteria. Hence, if the analogy between fermentation and contagion is sound, there are grounds for believing that more than one kind of bacterium may cause a specific infection; for example, diphtheria, cholera, and other infections may each be caused by one or more kinds of bacteria.

A bacterium is a one-celled vegetable micro-organism or plant, which is so very small that the highest powers of the microscope are often needed to render it visible. It is composed of a complex substance called protoplasm, which Huxley has named “the physical basis of life.” The cells have no visible nucleus, and may or may not have a limiting cell covering.

All classifications of bacteria are provisional, yet it is convenient to arrange them according to their growth and group-forms as they are at present understood. When the cells group themselves singly or in masses, which are more or less characteristic, they are termed micrococci. Those growth-forms characterized by the cells being joined together end to end to form rods or spirals, are called bacilli or spirilla. When the vegetative cells or spores of future bacteria grow within the bodies of bacteria, they are classed as endosporous varieties. On the contrary, when the spores are found differently, that is, outside the bacteria, they are said to belong to the arthrosporous variety.

Those bacteria which find in other organisms alone conditions suitable for their growth and development are called parasitic bacteria, while those forms which live upon dead substances are called saprophytes. In whatever form or shape the bacteria are found, whether as cocci, rods, or spirals, they are always one-celled organisms, and however much these cells may resemble each other in their appearances, these resemblances cease to exist when we compare the character of work which these cells are capable of doing. Vegetable and animal cells differ in this respect among themselves as greatly as do the animal or vegetable substances composed of such cells. We are familiar with the various kinds of tissue-cells of which the human body is composed; we know that some of them are glandular and are connected with the secretion of bile, gastric juice, etc.; or in the separation from the blood of certain products of tissue metamorphosis; that others enter into the formation of the nervous system, and are connected with volition and motion, others form bone or cartilage or muscle, etc. Now, the single-celled vegetable organisms known as bacteria differ as greatly among themselves in the character of work which they perform as do the tissue-cells of the human body. A few illustrations of this fact will not be amiss. We will briefly refer to the kind of work done by the micrococcus ureæ, the nitrifying bacteria, the bacteria of the mother of vinegar, the bacteria of lactic acid fermentation, and the bacteria of the decomposition of proteids.

The micrococcus ureæ consists of round cells, microscopic in size, which may be formed singly or joined end to end like a

string of beads; this organism converts urea into carbonate of ammonia; it is capable of doing this not only in the urine, but a pure culture of this organism will do the work just as readily if added to a solution of urea.

Micrococcus nitrificans consists also of small round cells. This organism or microbe converts the compounds of ammonia which are found in the soil, or added to it for fertilizing purposes, into saltpetre, which is appropriated by growing vegetation. It might appropriately be called the granger microbe, for through its influence the growing crops are enabled to utilize the ammonia compounds of the soil, which would be useless without this agency. A pure culture of this microbe, if added to an artificial nutrient solution containing compounds of ammonia, does its work as effectively as though it were at home in its native soil.

Micrococcus aceti, another small round cell, is the agent by which alcohol is converted into acetic acid; the various methods used in the arts for making of vinegar are based upon the power of this microbe of converting watery solutions of alcohol into acetic acid.

Micrococcus lacticus occurs in the form of minute cylindrical cells, and is the microbe chiefly concerned in the souring of milk, by converting the sugar it contains into lactic acid.

Bacillus amblyobacter is the microbe of butyric-acid fermentation. It vegetates in the form of slender cylindrical rods, and is one of the most widely diffused and important and varied in its powers of decomposition. In addition to the important part it plays in the manufacture of cheese, it is a specially active agent in destroying the cellulose of cell-membranes in the decomposition of decaying plants. In the process of rotting hemp, flax, and other textile plants, in order to obtain the fibres, this microbe plays the all-important part. Van Tiegham attributes to this organism an important part in the nutrition of ruminant animals. He claims that it vegetates in their stomach and splits up the cellulose of their food into soluble products. For illustration of the bacterial decomposition of the proteids we will refer to the bacterium *termo* (the drum-stick bacillus of putrefaction). Its uses in the economy of nature—for example, in disposing of dead animals—are sufficiently apparent to require no specification.

Were it not for this microbe, it would be a serious matter to know how to dispose of dead bodies. If it was necessary many other examples of friendly microbes, those necessary to man's comfort or his safety, could be cited to illustrate the power which these organisms have of decomposing or splitting up many substances. It will be seen, however, from what has already been said, that there is a striking difference among these lowly cells as to the character of fermentation or kind of work which they are capable of doing; thus one variety causes acetic, another butyric, and yet another lactic acid fermentation.

One of the objects of this paper will be to establish as a fact that the principles involved in fermentation are the same, regardless of the exciting cause, and that the products of fermentation will largely depend on the molecular structure of the exciting ferment. Before entering upon this subject I shall invite your attention to certain phenomena attending fermentation, and for illustration will describe that form which results in the production of alcohol. It is well known that vinous fermentation has for its ferment, or exciting cause, a small-celled vegetable organism generally known as the yeast fungus, and that brewers' yeast is entirely composed of these cells. When, under suitable conditions, yeast is added to a solution of malt, called "wort," fermentation will ensue, and alcohol will be the principal resulting product. One of the substances which the "wort" contains is sugar, and it is this sugar which the yeast-cells decompose and convert—at least ninety-five per cent. of it—into alcohol. The yeast-cells, like other organisms, multiply themselves by the generative act and thus increase in amount, so that the amount of yeast is a thousand-fold more at the end of fermentation than it was at the beginning. Alcohol, the principal product of vinous fermentation, is poisonous to the yeast-cells, and when, during the process of fermentation, a certain per cent. of alcohol is formed, fermentation at once ceases, and cannot be re-established until the alcohol, or a considerable portion of it, is removed. That fermentation occurs only in contact with the yeast-cells, and does not result from a hypothetical enzyme secreted by them, is established in the following way: Divide the fermenting vat or vessel into two parts by a membranous diaphragm, so that no

substance can pass from side to side except through the interstices of the membrane. Put your solution of malt equally into both sides, but put the malt in one side only. Now, all soluble enzymas, or other soluble substances contained in the malt solution, can readily pass through the diaphragm by osmosis, from one side to the other, forward and backward, but the insoluble yeast-plants are confined strictly to the side into which they were placed. Under these circumstances fermentation has been found to occur only in that side of the vessel in which the yeast-cells have been placed. An interesting, and, for our purpose, an important fact connected with this subject has been established by Oscar Brefeld, who, by a peculiar artifice, has so modified the yeast-cells in their structure that they can be made to grow and multiply in the solution of malt without producing a particle of alcohol;* the bearing of this fact upon one of the phenomena of contagion will become apparent further along. We are now prepared to point out the striking similarity in phenomena of fermentation, as set forth, and the phenomena of contagion.

Both are caused by one-celled vegetable organisms; these cells in each case are microscopic in size, and can be conveyed from place to place in various ways that will readily suggest themselves, and therefore require no special mention.

The cells of bacteria, like the cells of the yeast-plant, excite fermentation and decomposition when they are suitably environed. In the same manner that yeast-cells decompose sugar into alcohol, the cells of the micrococcus ureæ convert urea into carbonate of ammonia, the cells of the micrococcus nitrificans convert ammonia compounds into saltpetre, the cells of micrococcus lacticus convert sugar into lactic acid, and pathogenic bacteria-cells convert certain albuminoid molecules of the blood or tissues, of man and animals, into poisonous substances, ptomaines or toxines.

And again, as alcohol is poisonous to the yeast-cells and will arrest the fermentation which they excite, and by which it was produced, so ptomaines and toxines, the product of infection created by the cells of pathogenic bacteria, poison the bacteria

*Fermentation, Encyclopædia Britannica.

which caused their existence, and arrest the fermentation or infection which gave them life.

And finally: As the yeast-cells can be so modified in their molecular structure that they can be caused to grow and multiply in malt solution without producing alcohol, in a similar manner the cells of some pathogenic bacteria can be so modified by "attenuation," in various ways, that they are not only made harmless to man, but become a vaccine by which protection from the virulent microbes may be secured.

In all the examples of fermentation which have been cited, or, as a matter of fact, in all fermentations or infections, the products resulting from these processes, whether it be carbonate of ammonia, acetic acid, saltpetre, lactic acid, alcohol, or ptomaines or toxins, are invariably caused by cells decomposing or splitting up certain substances contained in the nutritive solution.

It behooves us, then, to inquire into the mechanism of this wonderful little cell, and to ascertain how, or by what method, it is capable of doing this work. At the outset, let me say that there are many things pertaining to the life-history, physical structure, and mechanism of the cell which are not understood; in fact, our knowledge of cell life and structure, beyond what is revealed by the microscope and chemistry, is very meagre. This subject offers an immense field for speculation and theory, which has not lacked cultivation. When there are not sufficient facts with which to build a theory, speculation becomes necessary to complete the structure, and often answers an excellent purpose, provided it is constantly guided and limited by established laws of chemical and physical science, and provided, also, that the theory thus constructed is found to be competent to explain the phenomena connected with, and belonging to, the subject. Now, the theory of cell-action which I offer, although largely speculative, complies with the conditions just stated. For a better understanding of this theory I will premise its discussion by the following statement of physical laws:

An elementary substance is the simplest known condition of matter. An atom is the ultimate part of such substance.

A compound substance is composed of dissimilar atoms. A

molecule is the smallest division of a compound substance which has the properties of the substance.

Each and every atom has a natural period of vibration from which it cannot be separated.

Force, the efficient cause of all physical phenomena, is motion, atoms, molecules, or of mass. Attraction, light, heat, and electricity are manifestations, or modes, of one and the same force; they are co-ordinate and subject to the laws of transmutation of energy.

As atoms have their equivalents of motion—for example, their laws of attraction, repulsion, and combination—which are inseparable from them, it follows that, when atoms combine to form complex substances, each one carries into the combination its equivalent of force or motion; this may be modified by the motion of associate atoms, but is never lost, and when the dissolution of the compound takes place, the departing atoms carry with them the same amount and kind of motion which they had originally.

All atoms, whether combined or uncombined, are in constant motion.

The atomic motions of each element observes definite periods of time in their recurrence.

Atoms of different elements observe different periods of time in their movements.

These prefatory remarks prepare us to recognize our little microscopic cell as a complex molecular substance possessing energy, and that this energy or power to do work is the result, and represents the total motions, of its contained molecules. If it was possible to magnify one of these cells to a size sufficient to enable us to see its atoms and molecules, what a wonderful sight would be offered us! How astonishing it would be to witness the arrangement of its millions of molecules, and millions upon millions of atoms, all in constant motion, and, under the rule of nature's laws, working harmoniously together for the common good. But even if it was possible, through any device of science or art, to witness the molecular structure and movements of a cell, we would yet be only upon the threshold of our investiga-

tion, and would still have much to learn regarding the life-history of the cell.

If all the facts of cell-life were known, then life itself would cease to be a mystery. It would become as an open book, because a knowledge of cell-life carries with it a knowledge of animal and vegetable life, inasmuch as animals and vegetables are simply arrangements, more or less complex, of cells arranged and differentiated, in accordance with natural laws, to perform various functions of the organism. It may, then, be safely asserted that within the compass of a little microscopic cell is concealed the mystery of life, and it is not improbable that life itself had its first manifestation, on this planet, in cell structure. In matters of lineage, the cells are pre-eminent the oldest inhabitants of the world; almost from the beginning of time, certainly from the beginning of organized life, these little bodies have been fighting for existence, and perhaps, like more complex but less humble organisms, have struggled for a betterment of their condition.

I can see no reason why the laws of descent and heredity should not apply with the same force to cell-life that they do to organisms of complex cell-life. If this is true, and the development of unicellular organisms occur along the same lines, and is governed by the same laws which control the development of multicellular organisms, then, in the early history of cell-life, certain complex molecular substances, favored by the peculiar environmental causes which must have prevailed at the time, developed into a multiplicity and diversity of cells. The differences manifested by the innumerable varieties of cells thus created would depend upon the differences in their molecular arrangements, and would cause the different varieties to develop in different directions; those varieties which were found to be in best harmony with their surroundings, best fixed in their molecular combinations, best able to successfully resist injurious influences, which perhaps would be fatal to the less favored sort, are the ones which would survive the struggle for existence and be selected by nature for propagation purposes. Now, as these selected varieties would transmit to their progeny their structural advantages, and from this progeny nature would again select the

fittest, thus, in accordance with the laws of heredity and selection, there would be a progressive development of selected varieties from generation to generation, through the long period of time since cell-life first began. In harmony with, and as a result of these laws of nature, cells and cellular organisms, in constantly adapting themselves to environmental causes, which themselves have been mutable and have been subject to the laws of progressive development, have passed from the simple to the complex, and from the undifferentiated to the differentiated cell-structures. Prominent among the environmental causes which determine the life and development of cells and cellular organisms are climate and cell-antagonisms.

Climatic influences are important factors in determining the geographical distribution of bacteria. For the same reason that every country has its own peculiar flora and fauna, it has also its indigenous bacteria. And as the flora and fauna may, by artificial means, be to some extent acclimated in foreign soil, so nature has provided that bacteria, when conveyed to foreign countries, may, under favorable atmospheric and climatic conditions, find in such countries conditions suitable for their growth and multiplication, at least for a time. In these facts are found an explanation of epidemic diseases which at times sweep over the country.

The subject of cell-antagonisms is receiving a great deal of attention from men of science. It is generally conceded that these innocent-looking little bodies do not dwell together in peace—on the contrary, they are constantly warring upon each other. In this "battle of cells," which has been waged since the beginning of cell-life, the survivors have learned, or acquired through heredity, certain means of attack and defense. It can be readily seen why qualities thus acquired and transmitted by heredity would be more firmly fixed in the cells of complex organisms, thus giving such organisms important advantages over simpler ones in the battle of cells. It will be observed, however, as in the battles between men, so in the battles between cells, skill does not always succeed against numbers.

In the light furnished by these facts, we will endeavor to ex-

plain in what manner, or by what method, the cell excites fermentation and causes decomposition of complex substances.

Picture in your mind's eye the marvellous mechanism of one of these little cells, with its contained molecules in active motion; remember the molecules are not in contact, but separated from each other by spaces which, although infinitely small to our comprehension, are really large when compared with the size of the molecules; remember, also, that the molecular movements are not of the hap-hazard sort, but are governed by fixed laws, and that while similarly constructed molecules have similar modes of motion, there are marked differences, in this respect, between molecules of dissimilar construction. As the molecule receives its motion from its constituent atoms, the cell must receive its energy from its constituent molecules. Remember that atomic and molecular motion constitute force, so that when we speak of cell-motion we mean to imply cell-force, its power to do work, and the explanation which is offered will follow almost as an inevitable result.

The explanation of differences in cell activities is based upon the law that force, the efficient cause of all physical phenomena, is motion—atomic, molecular, or molar; that heat, light, electricity, attraction, and repulsion, are simply modes of one and the same motion, which can be converted and changed from one into the other. Now, there is a marked difference in the kind of work which these different forces or modes of motion can do; for example, electricity can decompose many substances that light does not effect; on the other hand, light decomposes other substances over which electricity has no power; while heat, in its decomposing power, has a much larger range of action than either of the others.

The way or method by which these forces do this work, each of its own kind, can be better understood by means of an illustration. When a musical sound or note is made by any instrument, for example, with a violin, in a room containing an open piano, the same note will be sounded by this instrument. Now, sound is a mode of vibratory motion, and in the example cited, when the string of the violin is vibrated so as to cause a musical note, this vibration is communicated to the surrounding air, and

any musical instrument within reach of any of these sound-waves, if tuned in unison with them, will be thrown into vibration by them and produce the same note; the other strings or chords of the piano remain silent for the reason that they do not vibrate in unison with the note made by the violin; more correctly speaking, only that chord will vibrate whose period of vibration is equal to that of the string.

In the ears of all animals there is an arrangement of rods and hair-cells constituting what is known as the organ of Corti; this has been likened to a "harp of a thousand strings." I do not vouch for the supposed resemblance to a harp, but it at least can be asserted that the rods and hair-cells are arranged in such a manner that they can vibrate in unison with all vibrations whose period of time lies within certain limits. Some of the rods or hair cells are tuned in unison with one note, that is, they vibrate in the same period of time, while others are vibrated by other notes. In every instance, however, the little rods and hair-cells take up the refrain, or are vibrated only by those sound-waves having the same period of vibratory recurrence.

Light is another mode of motion, and, like sound, has its waves, which differ among themselves in their periods of recurrence. The different colors of light are produced by the different wave-lengths. In the retinal coat of the eye there are little rods and cones which vibrate in harmony with the different wave-lengths of light: some are vibrated by one color and others by other colors. In every instance the vibrations of light must be in unison with that of the rod or cone before the color can be recognized.

When waves of light or heat or water meet other waves of the same substance, in such a manner that the crests of one set will correspond with the crests of the other set, and the troughs of one will correspond with the troughs of the other, the waves will be enlarged, increased in amplitude.

Now, it is assumed that different varieties or species of cells have molecular vibrations, which, in their periods of recurrence, are distinctive of such species or variety: hence the molecular movements of cells are influenced in a certain way by other cells whose molecular periods of vibration coincide with those of the

first in point of time. The wave-crest and trough from one cell striking the molecular waves of another cell less firmly fixed in its structure, crest to crest and trough to trough, the motions of the first would necessarily increase the swing of the second until the cell-molecules were swung beyond their attractions and the cell disrupted. The cell-molecules thus set free would recombine in accordance with chemical laws to form simpler compounds; for example, in the vinous fermentation the molecular combinations of the yeast-cell are so timed in their motions that they can swing the molecules of sugar, held in solution, beyond their chemical attractions, and thus cause a disruption of the sugar; at the same time the molecules or atoms thus liberated recombine to form a simpler compound, alcohol. Other cells cannot do this work, for the reason that their molecules do not vibrate in the required periods of time. In the same manner the micrococcus aceti decomposes alcohol into acetic acid, and other bacteria perform their special kinds of work and are incapable of doing the work of other varieties. In the same manner, pathogenic bacteria shakes apart certain cellular albuminoid molecules in the blood or tissue of man and animals, while the recombination of molecules thus liberated form poisonous alkaloids called ptomaines and toxins, which are the immediate causes of the symptomatology and pathology of infectious diseases. The decomposition of albuminoid molecules by cell metabolism, principally bacteria-cells, and the influences which the products of this action, ptomaines and toxins, have in the causation of disease, is a subject of greatest importance to the physician.

The albuminoid molecules, from whatever source derived, present certain lines of separation, like the lines of cleavage in crystals, along which they are most easily disrupted or shaken apart by cell-vibrations; hence the character of the decomposition product depends along which of these lines separation has taken place. "At least three distinct series of chemical bodies are formed, viz., an acid series, an aromatic series, and a basic series. Out of the innumerable products arising from the action of the bacteria cells upon albuminoid molecules, and which have been extracted and studied, will be mentioned indol, cresol, and skatol in the aromatic series, creatine in the basic, and uric acid in the

acid series, serving only as mere examples" (*Journal of the American Medical Association*). "Cells other than those of bacteria are also capable of decomposing albuminoid molecules, and thus produce poisonous substances, *e. g.*, in the physiological changes from albumins to peptones there is a change from innocent to toxic bodies; this may be illustrated by the hypodermic injection of the digestive leucomaine of fibrine by pepsin. It occurs practically when, after the too hearty meal, the liver is unable to care for the excess of digestive leucomaine, and they escape into the general circulation, producing somnolence, lassitude, or even stupor." (*Journal of the American Medical Association*).

On this subject Dr. Joseph Leconte says: "The leucomaines, although formed by normal physiological process, are highly poisonous and inimical to health, unless speedily eliminated by appropriate organs. If, now, there should be a failure to eliminate these toxic elements, the results would be similar to those produced by disease germs, except that they would lack the quality of contagiousness, because they are not due to the presence of microbes. The liver is the organ principally concerned in the elimination of leucomaines" (*Journal of the American Medical Association*).

"If alkaloids, by the conjugation of 'S' biliary acids, if carbohydrates they escape the liver, and are taken care of by the blood and pancreas. If belonging to the class of phenols they are combined with a sulphuric radical, and when that gives out, are then combined with a glycosuric acid, and thus rendered innocuous" (*Journal of the American Medical Association*).

It is thus shown that fermentation may be the result of molecular motion, and that this process would take place whether the necessary vibrations originate in yeast-cells, bacteria-cells, or digestive ferments, which are the efficient cause of normal digestion. The principles involved in each case, the *modus operandi*, are the same in all. At this point, however, the similarity of results existing between the bacteria ferments and digestive ferments ceases. There is an important difference in their biological history, which carries with it an important and practical distinction. I refer to the fact that bacteria and yeast-cells are living organisms, capable of multiplying themselves by the

generative act, and hence, in the case of pathogenic bacteria, are capable of inducing contagious and infectious diseases. On the other hand, the digestive ferments are molecular combinations, which have no powers of self-multiplication, and cannot cause disease of an infectious or contagious character. There is a wise and beneficent law of wide application, the operation of which controls the course and duration of infectious fevers; this law is based upon the fact that the products of cell-decomposition are poisons which destroy the cells, or the fermentation, or infection which they excite. Thus alcohol is destructive to the yeast-cells and the vinous fermentation, while acetic acid, butyric acid, and lactic acid will arrest the fermentations of which they are the products, and, in the same manner, ptomaines and toxins arrest the infectious diseases of which they are severally the causes.

On this subject Dr. Klein says: "One of the most interesting facts observed in the growth of septic micro-organisms is this, that the products of the decomposition, started and maintained by them, have a most detrimental influence in themselves, inhibiting their powers of multiplication; in fact, after a certain amount of these products have accumulated, the organisms become arrested in their growth, and finally may be altogether killed." *

Pasteur says: "Many microbes seem to give rise during their breeding to substances having the property to be harmful to their own growth." †

It is evident that the periods of time in which occur the molecular vibrations of any given cell must swing in perfect unison with the vibrations of any other cell, or molecular structure, before the first can swing apart the molecules of the second. Crest must correspond to crest, and trough must correspond to trough, before the one set of vibrations can sufficiently increase the other to cause its disruption. When the arrangement is complete, *e. g.*, the vibrations of the bacteria-cell coincide in their periods of recurrence with the molecular vibrations of the albuminoid molecular substance, and decomposition of this results, thus liberat-

*Micro-organisms and Disease.

†Comptes rendus, Academy of Sciences, October 26, 1885.

ing its constituent molecules. It is evident that no new compound can form from these molecules unless its periods of vibratory recurrence do not coincide in point of time with those of the bacterium cells; the same influence which disrupted the albuminoid molecules would prevent the forming of other compounds having the same periods of vibratory motion; in fact, they must be of an opposing kind in order not to be influenced by the bacteria-cells. Now, it is again evident that when a ptomaine, possessing a molecular vibration which antagonizes that of the bacteria accumulates in a sufficient amount, the antagonism which it offers will be sufficient to arrest the motions of the bacteria-cells, and thus put a stop to the cell-metabolism which they caused—in other words, to arrest the disease.

Perhaps this power, which waves or vibrations have of increasing or destroying similar waves or vibrations, may be better understood by reference to instances where waves of sounds and waves of light thus influence each other. Take, for example, two tuning-forks, which have equal periods; when sounded each will give out the same continuous musical sound. Let us, however, change the vibrations in one of the instruments, by attaching some substance to it, or in any other way. The two instruments will no longer vibrate together, the vibrations will not coincide in time, hence the sound that will be given off by them will no longer be a continuous musical note gradually fading away, but will be a rising and falling sound. When the two instruments vibrate together, the sound will be distinct. As one vibrates more rapidly than the other, they will gradually part company, and the sounds which they give out will coincide less and less in point of time as one gains upon the other, and becomes fainter and fainter, and disappear when the wave crest of one coincides to the wave trough of the other. After passing the line, the sound becomes gradually more and more distinct, until it again reaches its acme, when crest and trough coincide to crest and trough of the other side, and thus the sound will rise and fall, depending upon the amount of wave interference or antagonism, until the vibrations are exhausted.

It is thus seen that sound-waves can be caused to so act upon each other that, instead of producing sound, they will cause

silence. Illustrations could be given, if it were necessary, to prove that when waves of light are met by other waves of light whose periods of vibrations are one-half wave length behind the first, darkness will be the result. The waves of the one set are quenched or antagonized by those of the other, in accordance with the law of wave interference. This beautiful and important law was discovered by Dr. Thomas Young, one of the most remarkable men the world has produced. Speaking of this law, Sir John Herschel says: "This principle, regarded as a physical law, has hardly its equal for beauty, simplicity, and extent of application in the whole circle of science." The principles involved in this law of interference furnish an explanation why ptomaines are inhibitory, and sometimes poisonous, to the bacteria-cells which originated them. The amount of antagonism exerted by the ptomaines, in accordance with this theory, would depend entirely upon the extent of interference which its molecular waves would cause in the molecular waves of bacterium cells. As the amount of interference in waves of sound and waves of light varies, and thus produces variable amounts of sound from zero up, there are ptomaines, whose inhibitory power over the actions of cells differs in the same degree and from similar causes.

SUMMARY.

The explanation of the phenomena of contagion which our theory offers is based upon the application of the laws of wave-motion to the motions of complex organic molecules; thus, when waves of sound, of light, or of water meet other similar waves, the amplitudes of the resulting waves are increased; when, however, the waves are dissimilar, the amplitudes of the resulting waves are diminished. As a means of illustration we will apply these laws to waves of water. Now, a wave of water has certain dimensions, *e. g.*, it has a front, a back, a crest, a trough, and has amplitude. The crest is the top, and the trough is the bottom of the wave, amplitude is the distance from the top of one to the top of the next (nearest) wave.

Now, when two bodies of water, approaching each other from opposite directions, meet, if the waves of each body coincide in the time of their upward and downward movements, the result-

ing waves will have their amplitudes enlarged, *i. e.*, the distance from crest to crest will be enlarged; if, however, the approaching waves do not coincide in time, should the crest of one set coincide with the trough of the other set, the amplitudes of the resulting waves will be diminished; or the downward force of one set of waves meeting the upward force of the other set, the result may be a complete antagonism of forces and the waves may be destroyed.

Assuming that the movements of complex organic molecules are also governed by these laws, it follows that when molecular waves of one combination meet molecular waves of another combination, the waves of the first coinciding with those of the second, the amplitudes will be increased in the waves of that substance which is the least firmly fixed in its structure; this increased amplitude means an increased distance between such waves, and when the distance is sufficiently great to remove the molecules beyond the limit of their attractions the combination becomes disrupted and the molecules liberated. It is well known that these liberated molecules cannot long remain in this free condition, they will be forced, by their mutual attractions, to recombine into combinations of simpler, and, for this reason, more fixed substances. It follows, as a result of these disrupting forces, that this new combination must have periods of molecular vibration that do not coincide with those of the disrupting cause. Hence, the molecules of this new compound will interfere with the movements of the molecules of the other substance, and, when the interference is sufficient, will destroy them, just as interfering water-waves destroy other waves of water. In harmony with these facts we can understand how the molecular movements of a bacterium cell disrupt the molecular combination of albuminoids, and why the ptomaines, which result from the re-arrangement of the liberated molecules, have the power of arresting or destroying through their interference the destructive forces of the cell.

IMMUNITY—HOW SECURED.

Immunity signifies a condition of body which opposes the development of infectious processes, or, more accurately stated, it

is a condition of the body which opposes the invasion of bacteria. We will not stop to discuss the many theories—beautiful, ingenious, but incompetent—which have been suggested in explanation of how immunity is secured, but will proceed to show that an application of the laws of wave-motion to organic molecules, together with the application of the laws of descent to the evolution of cells, will furnish a complete explanation of all the known phenomena of immunity.

The physical and biological premises upon which this theory of immunity is built postulates the necessary existence of a natural law of immunity from bacterial influences, through the operation of which all organisms, both animal and vegetable, are to a large extent rendered immune from the action of bacteria-cells: the exceptions to the universal prevalence of this law constitute individual or racial susceptibility to infectious processes. Hence, it becomes necessary to explain the causes of this natural law of immunity, and later, to indicate and explain the causes of its exceptions. That man and animal are, as a rule, exempt from bacterial invasions is evident; were it not for this law man would be destroyed by the hordes of microbes which surround him and which would attack him from all sides, which enter his body with the air he breathes, with the food he eats and with the water he drinks. In the face of such a vast army of foes he would be absolutely helpless, if it were not for this natural law of immunity. It will perhaps be answered that the reason man escapes injury from this horde of bacteria is to be found in the fact that they are innocuous. This answer is only partially true, for while they may be innocuous to man, they are frequently virulent to other animals; besides, this answer does not carry with it an explanation of why they are innocuous to man. The answer to this inquiry will necessarily include an explanation of the natural law of immunity. An investigation into the working of this law discloses the fact that differences exist among different races of people, and, to a less extent, individuals of the same race, regarding the kind of immunity which this law secures to them; *e. g.*, it is established that certain races are largely immune from yellow fever, and other races from syphilis, while individuals of these several races possess different degrees of susceptibility to these

influences. Admitting that this racial, and, to a less extent, individual, immunity may in part result from long exposure to the infecting causes, the principal cause, it must be conceded, rests upon structural differences between the races. In a series of articles, published in *The Lancet* in 1888, upon the pathology of infectious and infective diseases, Dr. Joseph Coates, the eminent pathologist, in discussing the causes of natural immunity, uses the following language in the summing up of his conclusions: "We have seen that, in the case of a large number of diseases of this class, inheritance, whether we take it more broadly in the race, or more particularly in the family, has an undoubted, and frequently a very great, influence on the susceptibility to infection. This varying degree of susceptibility exists in the cases of diseases which are demonstrably due to a micro-organism which is pathogenic in the individuals of one race to a high degree, and is non-pathogenic, or nearly so, in individuals of another race. Recurring to our remarks on the general principles of inheritance, it seems necessary to refer this difference in susceptibility to fine differences in the structure and activity of the tissues. We have seen that the differences in the races depend on variation in the details of their tissues." There are two theories of immunity before the world for a verdict, to which we must devote some attention. The theory of phagocytosis ascribes to certain cell-elements, *e. g.*, the white blood-cells, connective-tissue cells, endothelial cells, and cells of spleen, bone, marrow, and lymph-glands, which are generically called phagocytes, the property of attacking and devouring bacteria. It is said they cannot devour the pathogenic forms until they have been put through a system of training with the attenuated ones. Metchnikoff is the founder and leading advocate for this theory, other eminent bacteriologists, however, have verified the work done by Metchnikoff, and are equally zealous with himself in asserting the truth of the theory. The second theory ascribes to the normal tissue-fluids of the body a germicidal action. This theory is based upon carefully conducted experiments by Nutt, Büchner, Labarch, and Prudden with blood serum and other tissue-fluids, associated with and also separated from their cellular elements; and, it is claimed, proves that these fluids, and not the

cells they contain, are highly germicidal to many, but not to all, bacteria. While one theory seems to oppose the other, in so far as one ascribes the germicidal action to the cell-elements, and the other to tissue-fluids and blood serum, although deprived of cells, this opposition in fact does not exist; for it is more than probable that both cells and fluids of the body are germicidal; at the same time the germicidal powers may greatly differ in important respects. While the fluids may be competent to destroy some varieties of bacteria, they may be incompetent to injure the other varieties, or the cells may be competent to resist bacteria that are inimical to the fluids. The following quotations from Dr. Prudden's article "On the Germicidal Action of Blood Serum and Other Body Fluids," may be heard with interest:

"To account for the disappearance of pathogenic bacteria in the body, either in the course of an acute infectious disease, or as the result of exposures which we may sustain unharmed, several more or less plausible theories have been evolved.

"That one of these which has attracted most attention partly because it has been most ably advocated, and partly because it lends itself most readily to experimental observation, is that called the theory of phagocytosis. This theory is too well known to require detailed exposition here; suffice it to say that it postulates the taking up into their bodies and the destruction there of living micro-organisms by certain lowly organized cells, especially the leucocytes. A large amount of very plausible experimental evidence has been adduced in favor of this theory, and a good deal of this evidence has been unconditionally accepted by medical men. Metchnikoff, the chief expounder of this theory, claims that this destruction of the life of the bacteria by being taken into the bodies of certain cells, phagocytes, is the exclusive means which the organism makes use of in resisting the incursions of pathogenic bacteria. An animal whose leucocytes can successfully battle with and eat up a given species of bacteria, according to this theory, enjoys immunity from its deleterious effects.

"But the doctrine of phagocytosis, at least in the scope which is claimed for it, appears to most unprejudiced observers less and less to commend itself the more facts and observations on which it is based are critically examined and judiciously interpreted.

"The series of observations on which this theory largely rests, varied and elaborated in many ways, indisputably teach this, that when micro-organisms are introduced into the body, either naturally or artificially, the phagocytes which gather around them may be found after a time to have taken more or less of the germs into their bodies, where they show the morphological evidences of degeneration, which indicate that they are dead. That this phenomenon does occur is well enough established, but that it should be interpreted as necessarily meaning that the micro-organisms are taken in the living condition into the bodies of the cells, and are there deprived of life, appears to be very doubtful indeed." This quotation is sufficient to indicate that phagocytosis, like the Scotch verdict, is not proven.

Let us now learn what Dr. Prudden has to say, in the same article, regarding the germicidal properties of blood serum and other tissue-fluids. We will quote from his summary, and the concluding remarks of the articles referred to:

"It will thus appear, as to the general result of all this recent work, that, first, blood serum possesses, though in different degrees in different animals, and in varying potency with the different bacterial species, a most marked germicidal power; that a similar germicidal power resides in fresh human non-inflammatory transudations. That this power is not directly associated with the formed elements of the blood or the transudates, but is in some way dependent upon their albuminoid constituents. It would further appear that this singular, and, apparently, most significant capacity of the body fluids, is intimately associated with the complex condition which we call life."

"The significance of these new discoveries would seem to be very great and far-reaching, and not only in explaining many obscure phenomena of the acute infectious diseases and in their bearing on immunity, but also in calling back the attention of therapeutical adventurers from germicidal warfare with certain forms of infectious diseases, to what appears to be a natural defense of the organism against bacterial invaders, namely, a healthy condition of the blood." . . .

"But our knowledge of this subject is too fragmentary and too

little digested to permit us to do more at present than follow the general indications of its lead. . . .

"The fact that one of the most abundant of the pathogenic bacteria, the *staphylococcus pyogenes aureus*, appears to be quite invulnerable to this destructive agency, would indicate the necessity of cautious inferences. . . .

"It is a little humiliating, though doubtless salutary, to find ourselves face to face with a series of phenomena which seems to lie at the very basis of the knowledge of acute infectious diseases, and yet able to say only that they are the result of the vital forces."

These quotations from Prudden's paper furnish us the salient features of the two theories of immunity, some of the objections which are urged against them, and evidence of their incompetency to explain all, or even a large part, of the phenomena of immunity; they also give us an idea of the character and extent of known phenomena of natural immunity, which must be rationally explained by any theory before its truth can be accepted.

The chief difficulties, as I conceive them, which stand in the way of a correct knowledge of the laws of natural immunity are found in the obscure vitalistic conceptions entertained regarding the structure and activities of tissue, and the laws of inheritance in their application to the evolution of cell-development. We will endeavor to show that structure is an arrangement of molecules in cells, and the differences of structure consists in differences of molecular combinations with their associated movements in definite periods of time; and that these varying forms of molecular aggregation, whether found in cells, in protoplasm, or in albuminoids, have resulted from the operation of the laws of natural selection, heredity, and adaptation. These views will no doubt appear to many persons quite startling, as do all declarations which seriously disturb the usual order of prevailing opinions of men. It can hardly be claimed, however, that they are untenable; on the contrary, they are based on accepted physical laws, and explain many phenomena which cannot otherwise be explained, whether these are observed from the stand-point of the physiologist, the biologist, the physicist, or the chemist. The

warrant for making this statement is found in the writings of Michael Forster, Professor Huxley, Professor J. Clerk Maxwell, and Julius Thompson; it is needless to say that the opinions of such men, in matters relating to their special departments of science, are entitled to the greatest respect. Professor Michael Forster, M. D., says: "We have, in speaking of protoplasm, used the words 'construction,' 'composition,' 'decomposition,' and the like, as if protoplasm were a chemical substance. And it is a chemical substance in the sense that it arises out of the union or coincidence of certain factors which can be resolved into what the chemists call 'elements,' and can be at any time, by applying appropriate means, broken up into the same factors, and indeed into chemical elements.

"This is not the place to enter into a discussion of the nature of the so-called chemical substances, or, what is the same thing, a discussion concerning the nature of the matter; but we may venture to assert that the more these molecular problems of physiology, with which we are now dealing, are studied, the stronger becomes the conviction that the consideration of what we call 'structure' and 'composition' must, in harmony with the modern teachings of physics, be approached under the dominant conception of modes of motion.

"The physicists have been led to consider the qualities of things as expressions of internal movements; even more imperative does it seem to us that the biologists should regard the qualities (including structure and composition) of protoplasm as in like manner the expression of internal movements.

"He may speak of protoplasm as a complex substance, but he must strive to realize that what he means by that is a complex whirl, an intricate dance, of which what he calls chemical composition, histological structure, and gross configuration, are, so to speak, the figures; to him the renewal of the protoplasm is but a continuance of the dance, its functions and actions the transference of figures." . . . "And the conception which we are urging now is one which carries an analogous idea into the study of all the molecular phenomena of the body."

We must not pursue the subject any further here, but we felt it necessary to introduce the caution concerning the word 'sub-

stance,' and we may repeat the assertion that it seems to us necessary, for a satisfactory study of the problems on which we have been dwelling for the last few pages, to keep clearly before the conception that the phenomena in question are the result, not of properties of kinds of matter, in the vulgar sense of these words, but of kinds of motion." *

Professor Huxley says: "The broad distinctions, which, as a matter of fact, exist between every known form of living substance and every other component of the material world, justify the separation of the biological sciences from all others. But it must not be supposed that the difference between the living and not living matter are such as to justify the assumption that the forces at work in one are different from those to be met with in the other. Considered apart from the phenomena of consciousness, the phenomena of life are all dependent upon the working of the same physical and chemical forces as those which are active in the rest of the world."

"It may be convenient to use the terms 'vitality' and 'vital force' to denote the causes of certain great groups of natural operations, as we employ the names 'electricity' and 'electrical force' to denote others; but it ceases to be proper to do so, if such a name implies the absurd assumption that 'electricity' and 'vitality' are entities playing the part of efficient causes of electrical or vital phenomena."

"A mass of living protoplasm is simply a molecular machine of great complexity, the total results of the working of which, or its vital phenomena, depend on the one hand upon its construction, and on the other, upon the energy supplied to it; and to speak of 'vitality' as anything but the name of a series of operations is as if one should talk of the horology of a clock."†

Professor J. Clerk Maxwell says: "Thus molecular science sets us face to face with physiological theories. It forbids the physiologist from imagining that structural details of infinitely small dimensions can furnish an explanation of the infinite variety

*Encyclopædia Britannica, 9th ed., Article Physiology

†Ibid., article Biology.

which exists in the properties and functions of the most minute organisms."

"A microscopic germ is, we know, capable of development into a highly organized animal. Another germ, equally microscopic, becomes, when developed, an animal of a totally different kind. Do all the differences, infinite in number, which distinguish the one animal from the other, arise from some difference in the structure of the germs? Even if we admit this as possible, we shall be called upon by the advocates of pangenesis to admit still greater marvels. For the microscopic germ, according to this theory, is no mere individual, but a representative body, containing members collected from every rank of the long-drawn ramification of the ancestral tree, the number of these members being amply sufficient to furnish not only characteristics of every organ of the body and every habit of the animal from birth to death, but also to furnish a stock of latent gemmules to be passed on in an inactive state from germ to germ, till at last the ancestral peculiarity which it represents is revived in some remote descendant." *

Julius Thomson, in his introduction to "Thermo-chemical Investigations," says: "Theoretical chemistry is based upon the molecular theory, according to which all matter is made up of molecules, and these molecules of atoms. The physical state of bodies depends upon the arrangement and motions of the molecules, the other physical and chemical properties depend upon the kind and number of atoms in the molecule, upon their arrangement and relative motions."†

In a former part of this article we endeavored to explain that certain cells would be virulent to other cells when the first were able to disrupt the molecular combinations of the second, and that this power of disruption was exercised by the more stable molecular combinations, whose periods of molecular vibrations coincided with the less stable in periods of recurrence. Under these conditions the cells of virulent bacteria, with their contained molecules vibrating in definite periods of time, would

*Ibid., article Atom.

†W. R. Nichols: Popular Science Monthly, October, 1883.

shake apart the molecules of other cells or molecular combinations, *e. g.*, the albuminoid molecules of the cell-elements or fluids of the blood or tissues of man, provided these vibrated in periods of time coinciding with those of the bacteria cells; for the reason that the first are more fixed in their molecular combinations than the second, and consequently are better able to withstand the increased kinetic energy manifested by an increase of wave amplitude, which molecular waves, rapidly superposed on other molecular waves of the same periods of recurrence, would necessarily induce.

Bacteria cells whose wave-lengths do not coincide in periods of recurrence with those of any cells, blood serum, or tissue fluids of man, would for this reason be innocuous to man. At the same time they might find, in fluids or tissues of other animals, molecular combinations which these bacteria could disrupt, and for this reason they would be virulent to such animals."

I presume that no one will deny that cell structure, or that of the normal tissue fluids of man's body, varies in many respects, and that these variations correspond to the ultimate use of such fluids in supplying the different cells of the body with the means of repair and regeneration. Admitting this proposition, it follows that different cells and different fluids of man's body, notwithstanding their macroscopic or even microscopic similarity of appearances, possess molecular combinations differing among themselves, and peculiar to each class or variety, and consequently cannot be affected alike, or at all, by the same bacteria; some bacteria would find vulnerable structures in the blood and other fluids of the body, others in the fixed cells, and others perhaps in the contents of the alimentary canals. Some would be virulent to man and innocuous to animals, others would be virulent to some animals and innocuous to others, and would thus present many differences of action—which in fact are found to exist in nature.

Cell structure is thus resolved into molecular combinations, while cell immunity is the result of molecular vibrations. Hence it follows that the law of natural immunity depends not alone upon inherited qualities acquired by man as a complex cellular organism, but also upon qualities which each individual cell or

molecular combination has acquired for itself through the operation of the laws of inheritance and adaption.

We have already endeavored to outline the results that would be obtained by the application of the laws of natural selection, heredity, and adaptation to the evolution of cell life.

In an infinite number of created cells there would exist infinite differences in their molecular combinations, which would determine species and varieties, and would also determine the lines of development which the different species and varieties would pursue, as well as the extent of development which the species and varieties could attain. Thus, in consequence of this molecular structure, some cells would find their fixed point of development in unicellular organisms, while others would enter into and assist in the formation of complex multicellular organisms. All cells from the beginning, in consequence of the differences in their molecular combinations causing equal differences in their molecular vibrations, would wage incessant war upon each other because of the actions, interactions, and reactions of their molecular vibrations, until there would eventually result an adjustment of their forces, through the operation of the laws of natural selection, heredity, and adaptation, resulting, to a great extent, in their individual and special immunity. By natural selection we mean that law of nature whereby she selects from a large number of organisms those varieties and species which are in best harmony with their environment. By heredity we understand that natural law which transmits through the race those qualities, possessed by varieties or species, which determine their selection by nature. By adaptation we understand that law which enables organisms, during their generation, to adjust themselves to their surroundings; qualities thus acquired may be, to a limited extent in long periods of time, transmitted through inheritance. Environment constitutes those natural causes, *e. g.*, climate, food-supply, temperature, moisture, etc., which determine the species or varieties which nature will select for the purpose of propagating the kind.

No correct opinion of cell life or the life of cellular organisms can be had. There can be no correct conception of the causes of cell immunity, whether it be a bacterium cell or one found in

man's body, or for that matter, found in the cells composing his entire body, that is not based upon the evolution of cell life, through the laws of descent from the simple to the complex, and from the undifferentiated to the differentiated cell structure. It is in this manner and in conformity with these laws, that man has acquired his natural immunity from bacterial invasions. The molecular vibrations natural to the various cells and fluids of his body render him immune to a great extent from what might be otherwise fatal influences. Now, these molecular cell combinations and their equivalent molecular vibrations are qualities of inheritance, and represent certain adjustments of molecular force gradually acquired by the ancient ancestors of these cells through wars and battles of cells, the like of which has never occurred in the history of man.

Having thus explained the causes which produced the laws of natural immunity, it would be proper to inquire into the reasons why this law is not absolute in its operations; why man is not immune from all infective and infectious diseases. To enter into this discussion and explain how the laws of natural selection, heredity and adaptation are equally as competent to explain these exceptions to the law as they are to explain the law itself, would make this already lengthy paper too long to be read on this occasion. I have concluded to pass this portion of our subject, and devote the remainder of this paper to an explanation of the principles involved in artificially acquired immunity. It is well known that immunity from many acute infectious diseases can be secured by artificial means, *e. g.*, one attack often renders the individual immune from future attacks of the same malady. Another artificial means of securing immunity is to be found in what is termed "protective inoculations;" this method consists in the inoculation of an "attenuated" or weakened form of the virulent microbe which is the etiological factor in producing the disease. Thus anthrax, chicken cholera, small-pox, swine plague, and other forms of infectious disease are non-infectious to individuals who have been previously inoculated with the attenuated microbes of that disease from which they seek immunity. "Attenuation" of bacteria is produced differently with different varieties of pathogenic bacteria, and when once accomplished is more or less

fixed as a condition of such bacteria. To all appearances they are the same, but are no longer able to decompose molecular substances, provided the attenuation is perfect; there are, however, degrees of this condition, so that the decomposing power of the bacterium will depend upon the extent of its attenuation. *i. e.*, at what point or stage the process of attenuation is arrested; thus the power of the cell to do its specific work is proportioned to the extent of its attenuation. While the attenuated bacterium is usually fixed in this condition, at least to a very considerable extent, and will transmit this quality to its offspring through many generations, it can, by a reversal of the methods of attenuation, be brought back to its original condition of virulency. You will, perhaps, be reminded of the similarity of behavior in this respect between the bacterium and the yeast-cells. Oscar Brefeld, you will remember, succeeded, by a peculiar artifice, in modifying these cells in such a way that they would grow and multiply themselves in a solution of malt without producing alcohol.

The third and last means by which immunity against an infectious disease can be secured, is by previously injecting its characteristic ptomaines into the individual, beginning with small amounts and gradually increasing the dose as the individual becomes accustomed to the poison. This means of immunity, by the injection of specific ptomaines, is of recent discovery, and bids fair to become of great practical advantage. It already explains what had been previously very obscure, how the pregnant mother gives immunity, for example, in syphilis, to the child in utero.

It is generally admitted that solid particles, like bacteria-cells, cannot pass from the mother through the placenta to her child in a normal state of the placental tissues; hence, the fact of the child's immunity secured through the mother was not understood. That soluble substances like ptomaines can pass in this way by osmosis is not questioned, and in doing so explains how the child receives from the mother immunity from syphilis and other infectious diseases.

These different means of securing immunity from certain infectious diseases, *e. g.*, immunity secured by a previous attack, immunity secured by protective inoculations with the attenuated

bacterium, or with the specific ptomaine, appear to be of a very dissimilar character, and cannot be harmonized by any of the theories at present offered in explanation of these processes. It will be observed, however, that when the principles involved in our molecular cell theory are applied to the elucidation of this problem, a striking similarity of action between these methods is seen to exist, and order is established out of chaos.

I will first invite your attention to the methods of securing immunity by inoculating attenuated bacteria and by inoculating the specific ptomaines, and show that practically the two methods are the same. We have previously explained how the pathogenic bacterium cell, through its molecular vibrations, has the power of disrupting the albuminoid molecules which it finds in the blood or tissue fluids of man's body, provided that the molecules of this substance vibrate in the same periods of time, crest to crest and trough to trough, in which recur the molecular vibrations of the bacterium cell. This is an important principle which I hope you will fix in your minds. When two or more molecular combinations—for illustration, two cells whose molecules vibrate in the same period of recurrence—meet in the blood, or any other nutritive solution where the molecular activities have full play, that cell which is best fixed in its molecular combinations will shake apart the molecules of the other cell, drive them beyond their attractions, and thus disrupt the cell. When this conflict is between the molecules of bacteria-cells and combinations of albuminoid substances, and the battle-ground is the tissue fluids of man's body, the albuminoid molecules will be driven beyond their attractions and the combinations disrupted, for the reason, first, that they vibrated in unison with those of the bacterium-cell, and second, that they are less fixed in their combination than those of the bacterium cell. Now, when this pathogenic bacterium cell is attenuated, weakened in its power of disrupting the albuminoid molecules, it will produce only small quantities of ptomaine; the amount of ptomaine produced will depend upon the amount of attenuation the cell has received. So that, using these attenuated bacteria as the matter of inoculation amounts to the same thing as using small quantities of ptomaine

as the matter for such inoculations; the results obtained and principles involved are the same in either case.

"How does one attack of an acute infectious disease give man immunity from other attacks of the same malady?" is the question that now offers itself for our solution.

A bacterium cell disrupts molecular combinations of the albuminoids when the molecules of each vibrate in the same periods of recurrence; the albuminoid molecules which are thus disrupted or shaken apart, and liberated from their former combinations, will again immediately recombine, because of their attractive affinities, to form other combinations which are called ptomaines. Explanation has been made why these ptomaines must of necessity have molecular vibrations which recur in periods of time that interfere with those of the bacterium cell, and when the ptomaine accumulates in sufficient amount will, through the action of the law of interference, which applies to all wave-motion, so antagonize the bacterium-cell that its action will be destroyed, and it will no longer be able to disrupt the albuminoid combination. It is in this way, you will remember, that the yeast-cells are affected by alcohol, their ptomaine, and it is this law of interference which explains why waves of light, or waves of sound, if they recur in different periods of time, may in the one case produce darkness, and in the other produce silence. You will observe that the reason the molecular vibrations of the ptomaine thus interfere with those of the bacterium-cell, is due to differences which exist in the vibratory recurrence of the two substances, and that molecular vibrations, like the vibrations of light and sound, are subject to that beautiful and far-reaching law of interference.

Now, as the molecular vibrations of the bacterium cell coincide in all respects with those of the albuminoid combinations which it is capable of disrupting, it follows that the respective ptomaines will affect or interfere with the two substances alike, *i.e.*, the molecular vibrations of two substances being the same, any third substance whose molecular vibrations would interfere with those of one substance, would also interfere with those of the other.

Hence the ptomaine which interferes with the bacteria cells will, for the same reason, interfere with certain albuminoid molecules. You will understand that this interference, exerted by

the ptomaine over the albuminoids, will change the molecular vibrations of this substance, that is, will change its molecular combinations, and as long as this interference, or this changed molecular combination, continues, such molecules could no longer be influenced by the bacterium cell, and the individual would be immune from that acute infection to which such bacteria stand in the relation of etiological factors.

Ptomaines are chemical substances, and like other chemical substances, do not find in man's body a permanent abiding-place, but are disposed of or eliminated from the body in a reasonably short time. How, then, are we to explain the more or less permanent immunity which observation and experience teach us is secured by the various artificial means which have been referred to?

The phenomena of interference, manifested in waves of light or waves of sound, continue only during the time that the interfering cause is in operation. You will observe that this rule does not apply to the interference between the ptomaines and albuminoids. How, then, are we to explain the fact that the phenomena of interference, manifested as change of molecular movements in the albuminoids of the blood, continue to persist more or less permanently after the cause of interference, the ptomaine, has been removed or is no longer a cause of molecular interference? To fully understand this problem, it is necessary to consider the nature of the two substances involved, the ptomaines and the albuminoids. This ptomaine, a product of the disintegration of the albuminoid, is a less complex and more fixed substance than the albuminoid from which it is derived. The ptomaine which will be produced in any given case is determined by the molecular structure of the active causes, the bacteria-cells, and the molecular structure of the substance acted upon, the albuminoids, as there are many varieties of the pathogenic bacteria and many differences in the molecular combinations of the albuminoids, there must result many different kinds of ptomaines. The albuminoids are of course derived from the food we eat, animal or vegetable. The molecular combinations which these substances had before entering our bodies, became greatly changed by heat in the process of cooking them, and fur-

ther changed by the process of digestion to which they are subjected. As we find them in the blood or tissue fluids of man, they are plastic molecular compounds, well suited to furnish to the many different kinds of cells of which man's body is composed, matter for their repair or regeneration. It follows that substances possessing such mobile molecular combinations of various kinds would be easily influenced by interfering bodies, and that the new molecular arrangements involved in this process of interference would be more or less permanent, and capable of being transmitted by the act of generation. That this is not an improbable assumption, but, on the contrary, a correct principle, is evidenced by the fact that changes of like nature in the molecular arrangements of cell structure, a much more fixed substance than the albuminoids, do occur from artificial causes, and that such new molecular arrangements become permanent, and are transmitted through the act of generation. I refer to those changes produced in the pathogenic bacterium by the process of attenuation.

Immunity will then be more or less permanent, depending upon the degree of permanency in the molecular combinations of the albuminoids which the ptomaine has imposed upon them. As a matter of fact infectious diseases differ very greatly, regarding the duration of immunity, if any, which one attack secures to the individual against other attacks. The phenomena, you will observe, in this instance, as well as in all others, are in harmony with and capable of being rationally explained by our theory. So far as I know, there is no attempt to harmonize an explanation of these phenomena with the theory of "enzymes" or, for that matter, with any other theory. The atomic theory is accepted, and, in fact, is the foundation upon which is built the beautiful and stately structure, Chemical Science, although no man has ever seen an atom, and for that matter, will never see one; yet it is accepted because it is capable of explaining chemical laws and the phenomena of chemical changes. It can also be said of the undulatory or wave theory of light, the waves are invisible and likely to remain so, but the theory is accepted because of its competency to explain the phenomena and laws of light. And, if you will excuse the apparent egoism involved in making these com-

parisons, it is because the molecular cell theory is competent to explain the phenomena and laws of infection and infectious diseases, that I am convinced of its truth.

It will, however, do more than this. I am convinced that a right application of the laws involved in this theory is competent to explain many other dark problems of medicine—for example, that obscure subject involved in the power and potency of drugs and their therapeutical uses; and I predict that it will be along these lines of investigation that knowledge is to be obtained and progress made.

AUSTIN, TEXAS, March 7, 1890.

